Biogeochemical Connectivity in Semi-Arid River Systems

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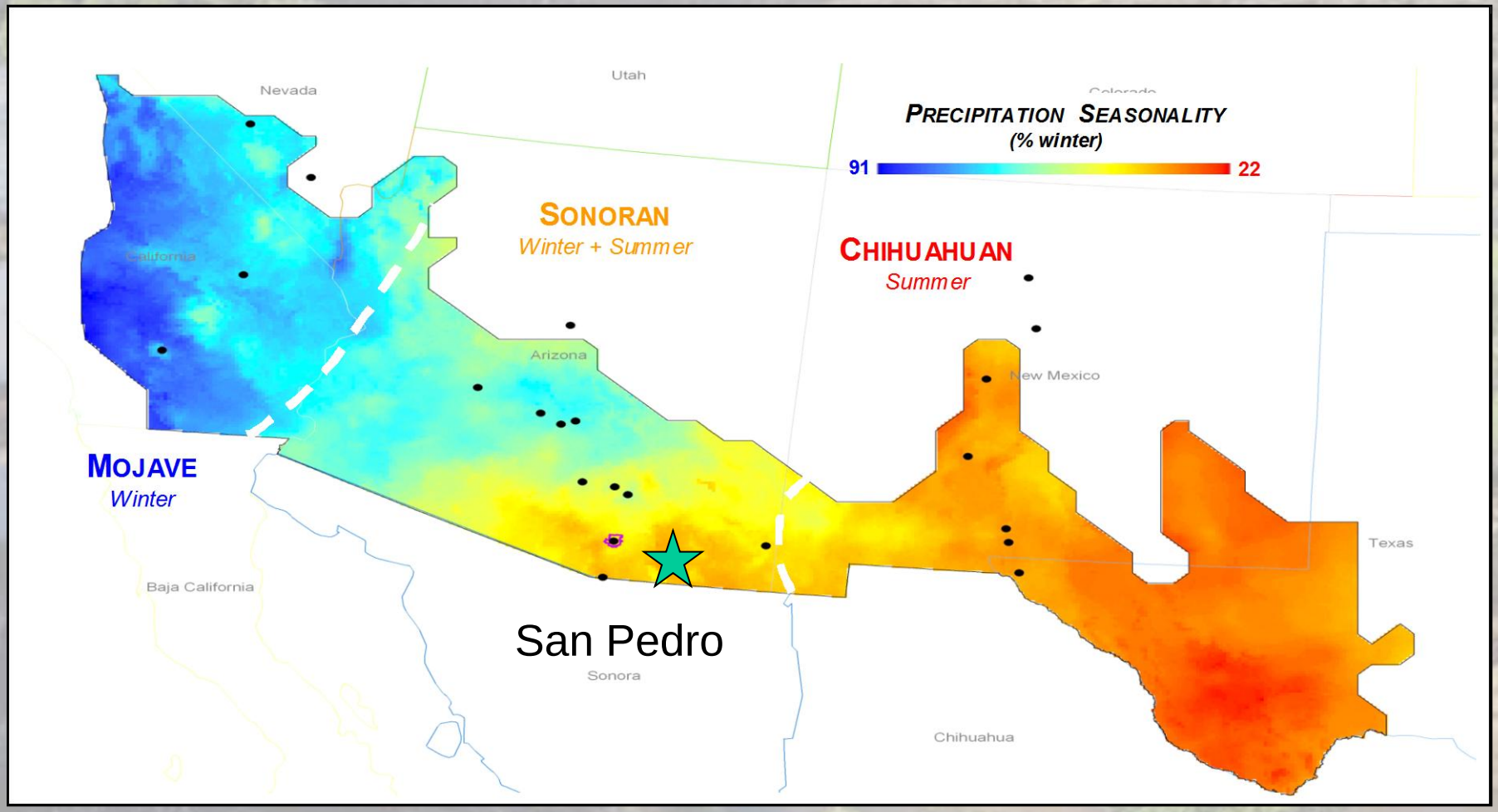
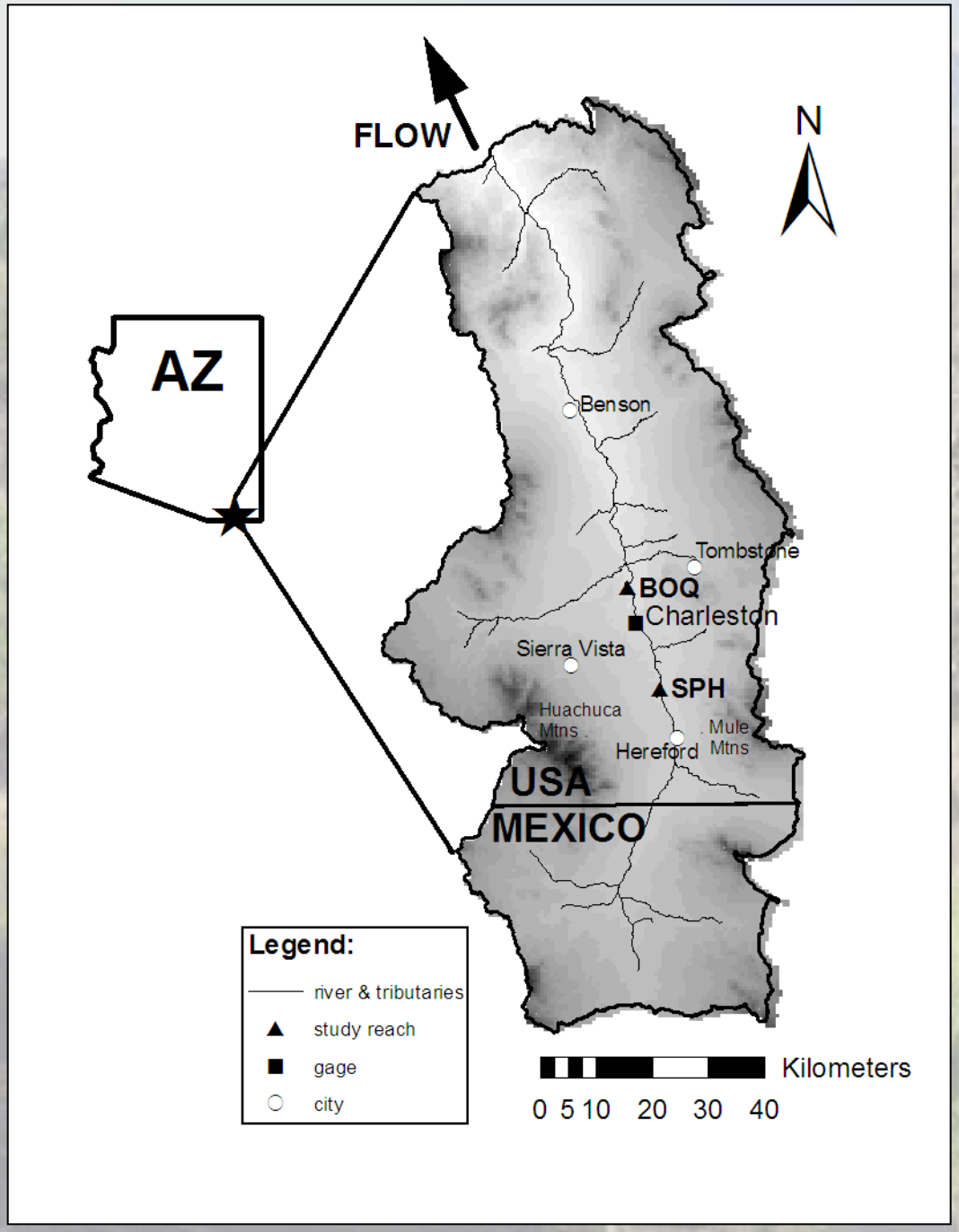
Outline

- Hydrology of arid and semi-arid systems
- Dissolved and particulate linkages of arid uplands to perennial rivers
- Influence on riparian biogeochemistry
- Riparian dynamics
- Two key points
  - Connections are infrequent but important
  - Runoff may be small but it is important

Precipitation Seasonality




FLOW
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AZ
Benson
Tombstone
BOQ
Charleston
Sierra Vista
SPH
Huachuca
Mtns
Mule
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MEXICO
Legend:
river & tributaries
study reach
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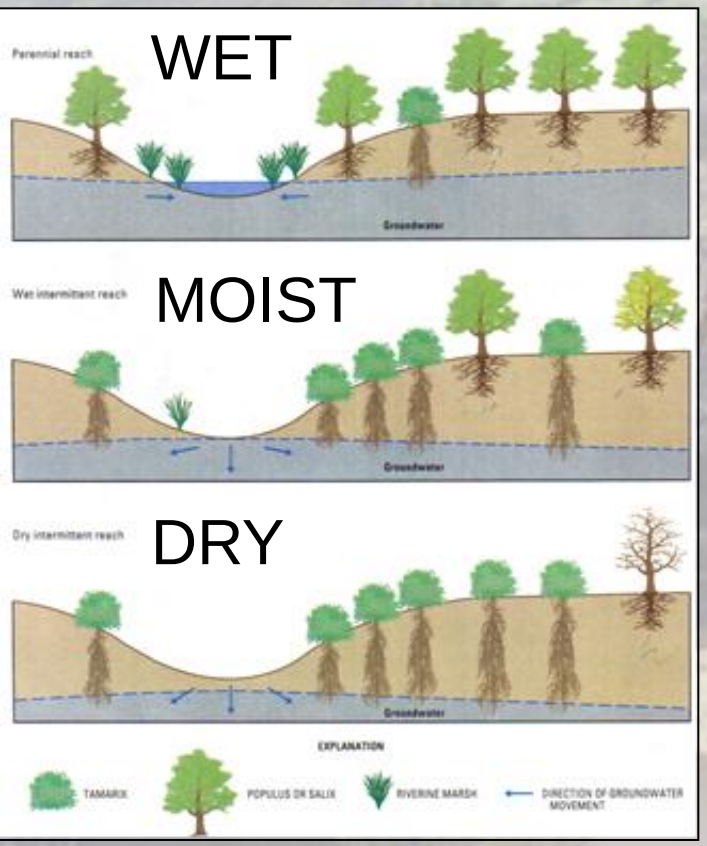
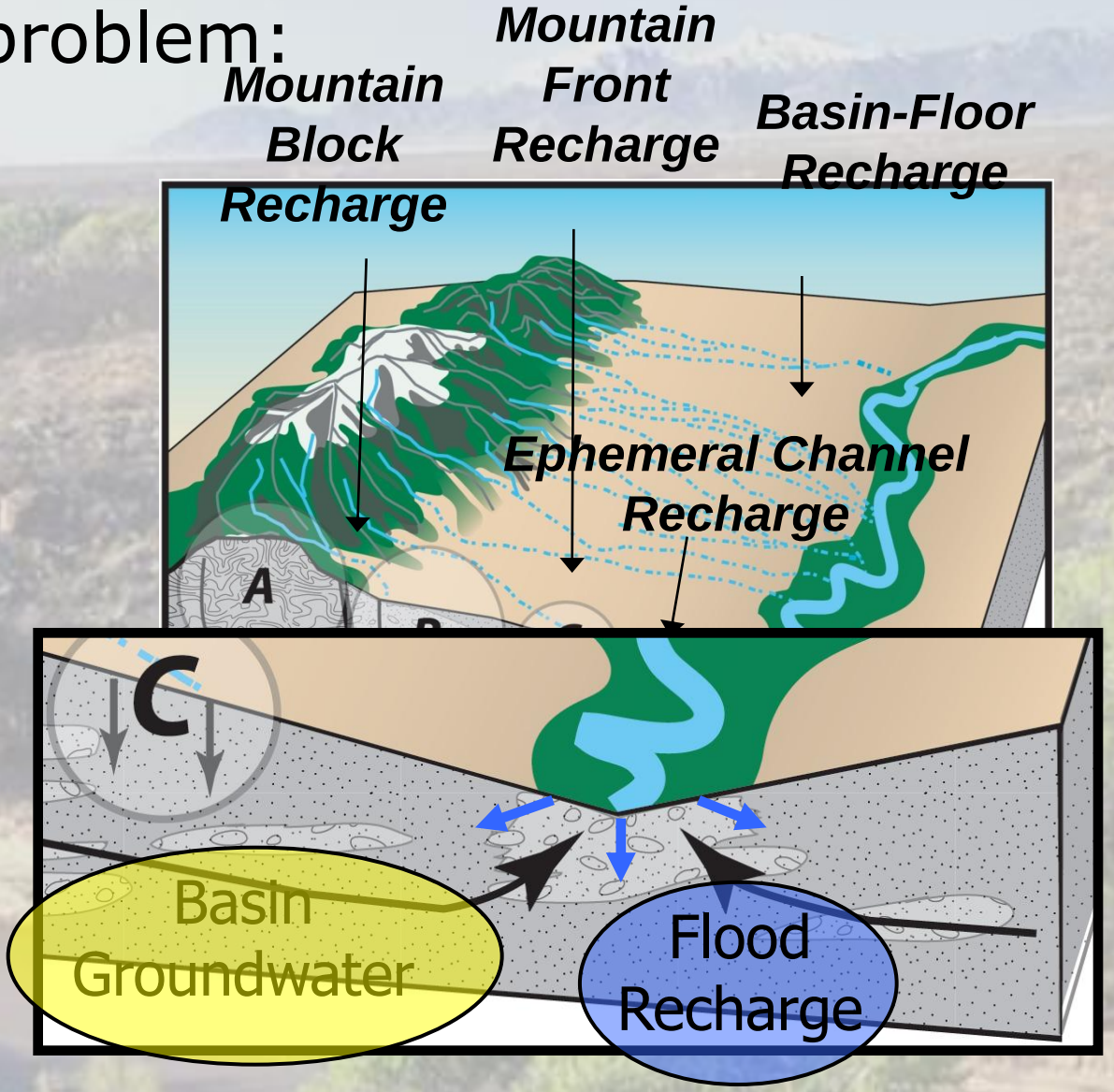
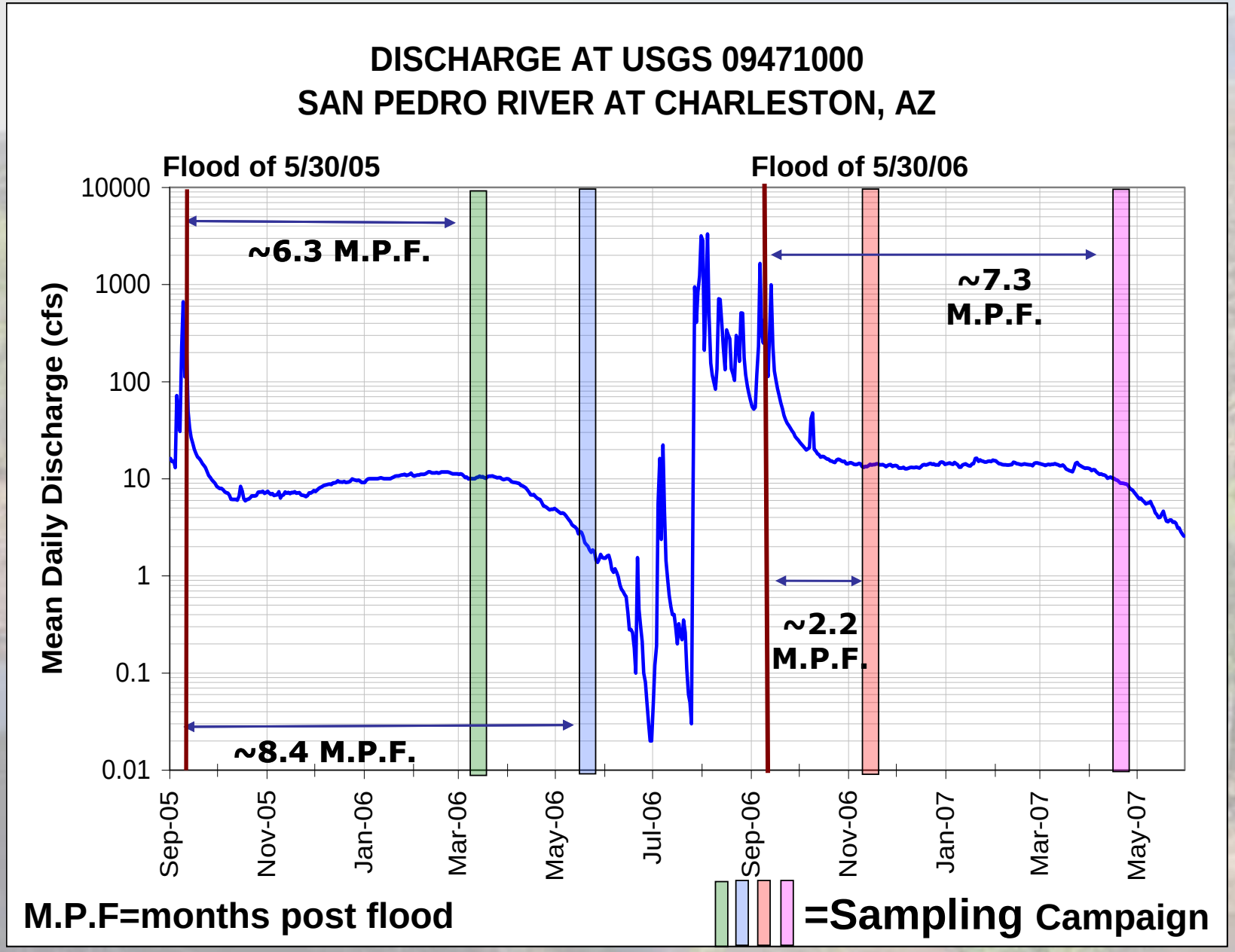
Kilometers
0 5 10 20 30 40

Statement of the problem:



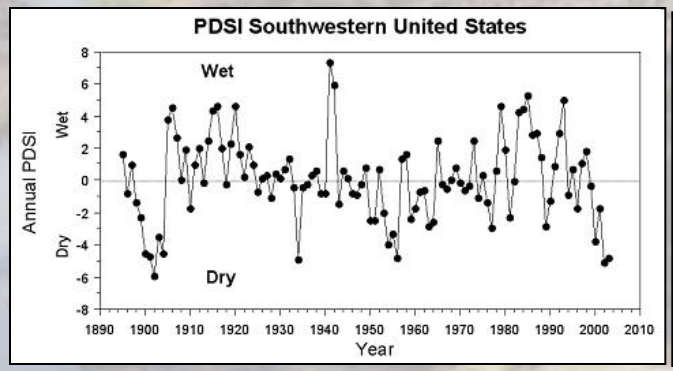


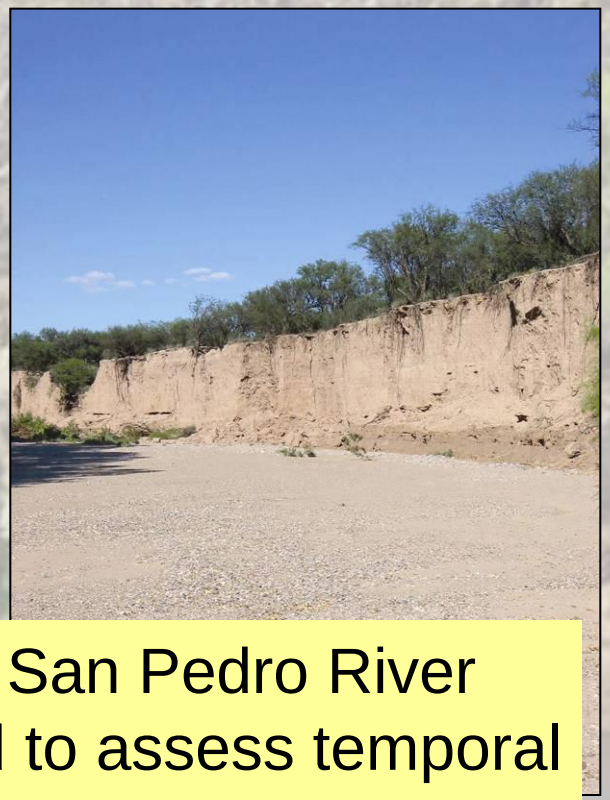


Personal Communication – Carlos Soto

Problem statement: Legacies of past extreme flood events may be shaping current vegetation trajectories and response to climate change.

Climate extremes + land use extremes ➡ Historic entrenchment of San Pedro River

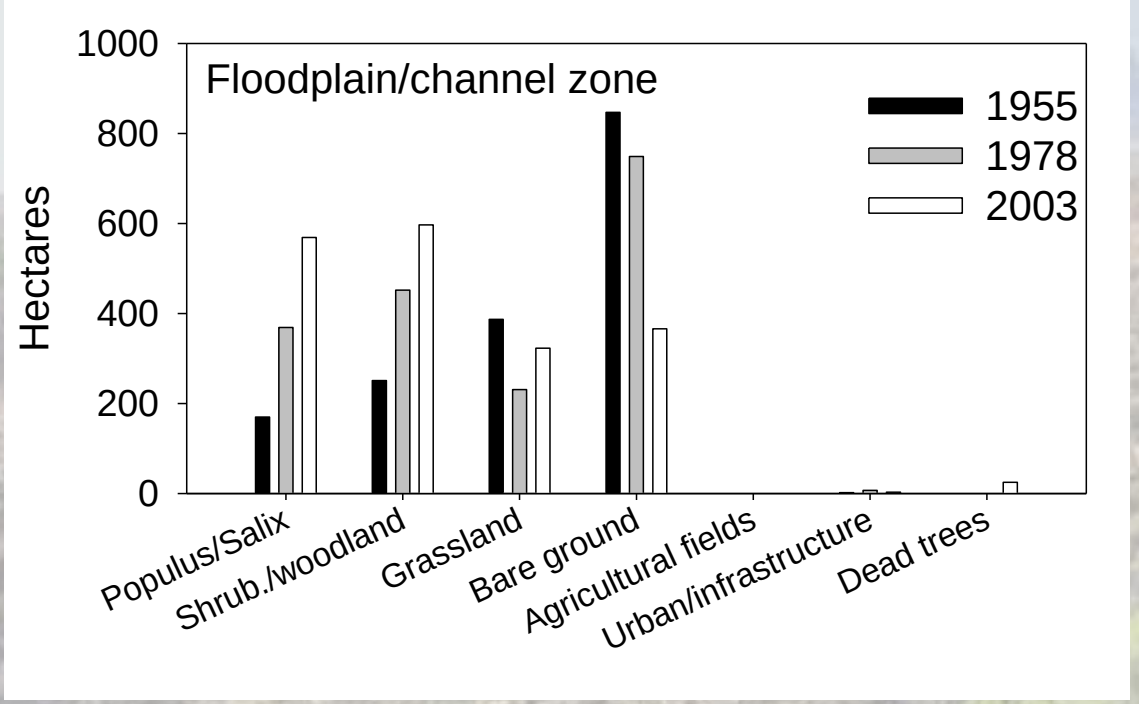




"It was probably during the 1896 flood that a channel almost 244 m wide and 6 m deep developed…" (Hereford and Betancourt 2009).

Methods: Aerial photographs of the Upper San Pedro River from 1935, 1955, 1978 and 2003 analyzed to assess temporal and spatial trends in vegetation cover type abundance.

Results: As a legacy of past extreme disturbance, pioneer woody vegetation has been expanding over past ½ century.



	Status in 2003				
	Populus Salix	Shrub./ wood.	Grass-land	Bare ground	Farm +urban
Status in 1955					
Populus/Salix	15%	3%	7%	9%	0%
Shrub./wood.	10%	46%	4%	23%	0%
Grassland	19%	22%	41%	18%	0%
Bare ground	56%	29%	48%	50%	0%
Farm + urban	0%	0%	0%	0%	0%
Sum	100%	100%	100%	100%	100%

Most *Populus/Salix* points mapped in 2003 arose from bare ground (as mapped in 1955)

Conceptual Model For Arid and Semi-arid Catchment Biogeochemistry

Nutrients - Move - React and Repeat

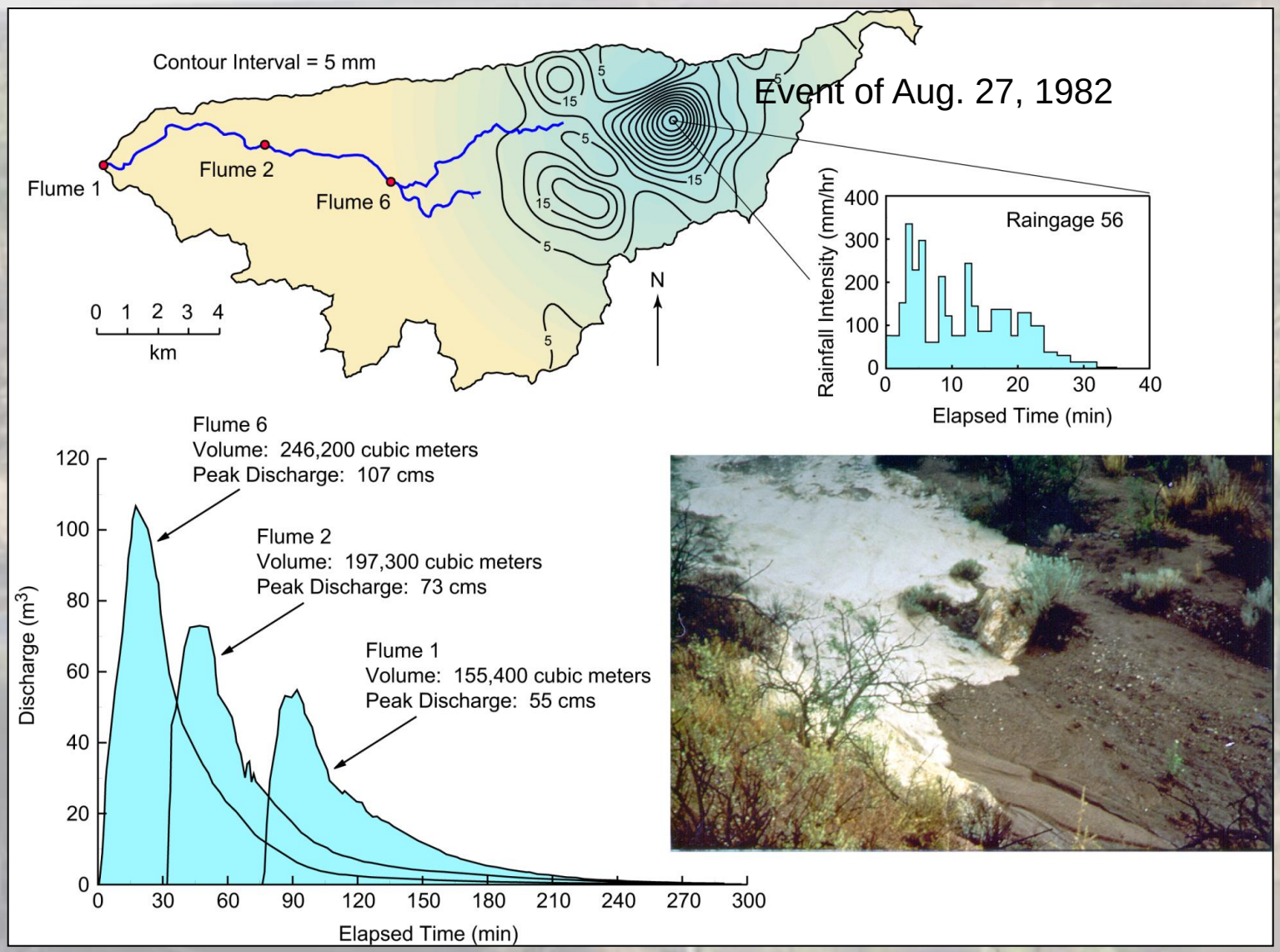
Arrive at riparian Area

Consistent Wet Conditions Allow for More reactions

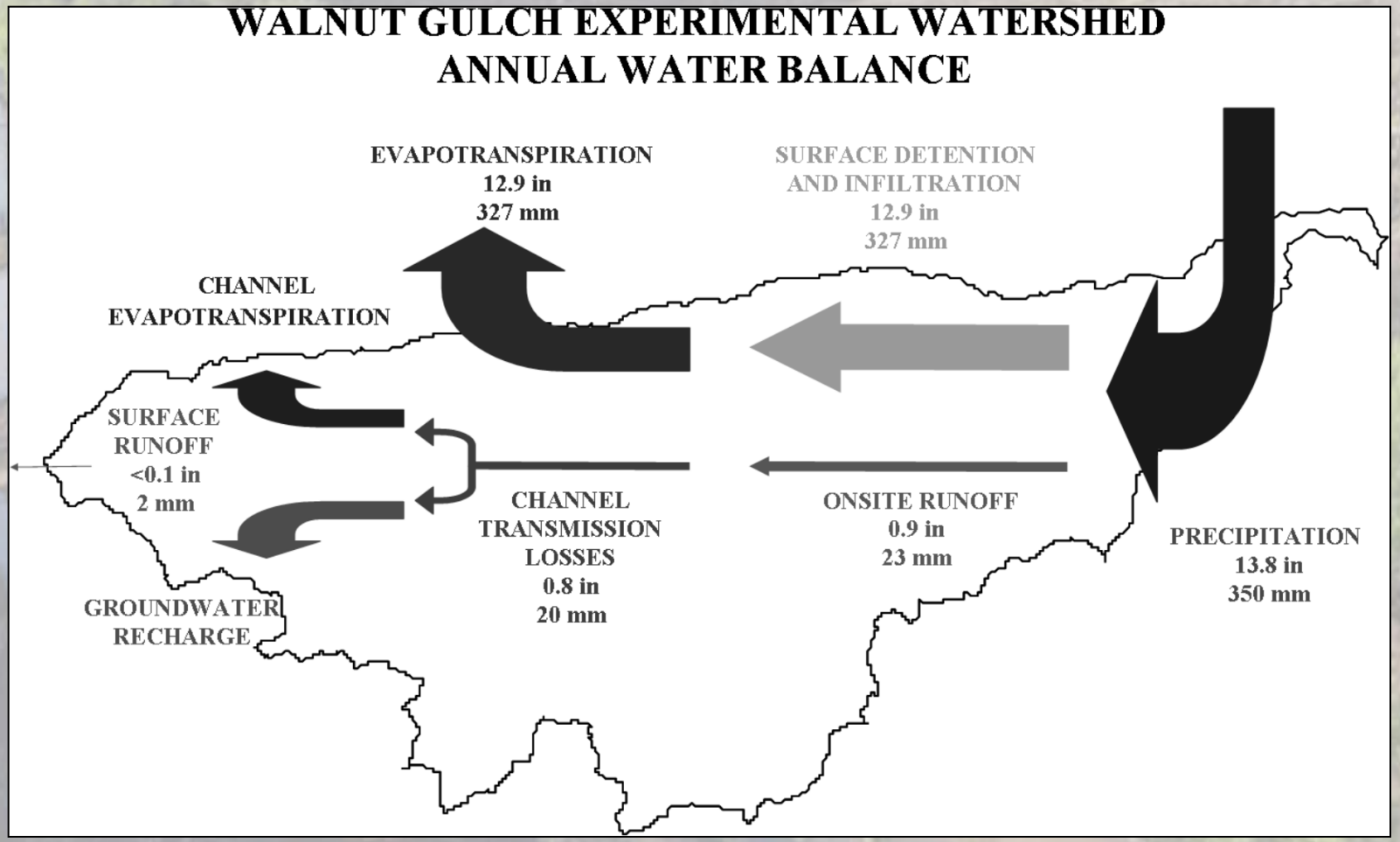
Continuous pumping by stream and ET allow for continuous mixing

Dry conditions may allow disconnection within Riparian

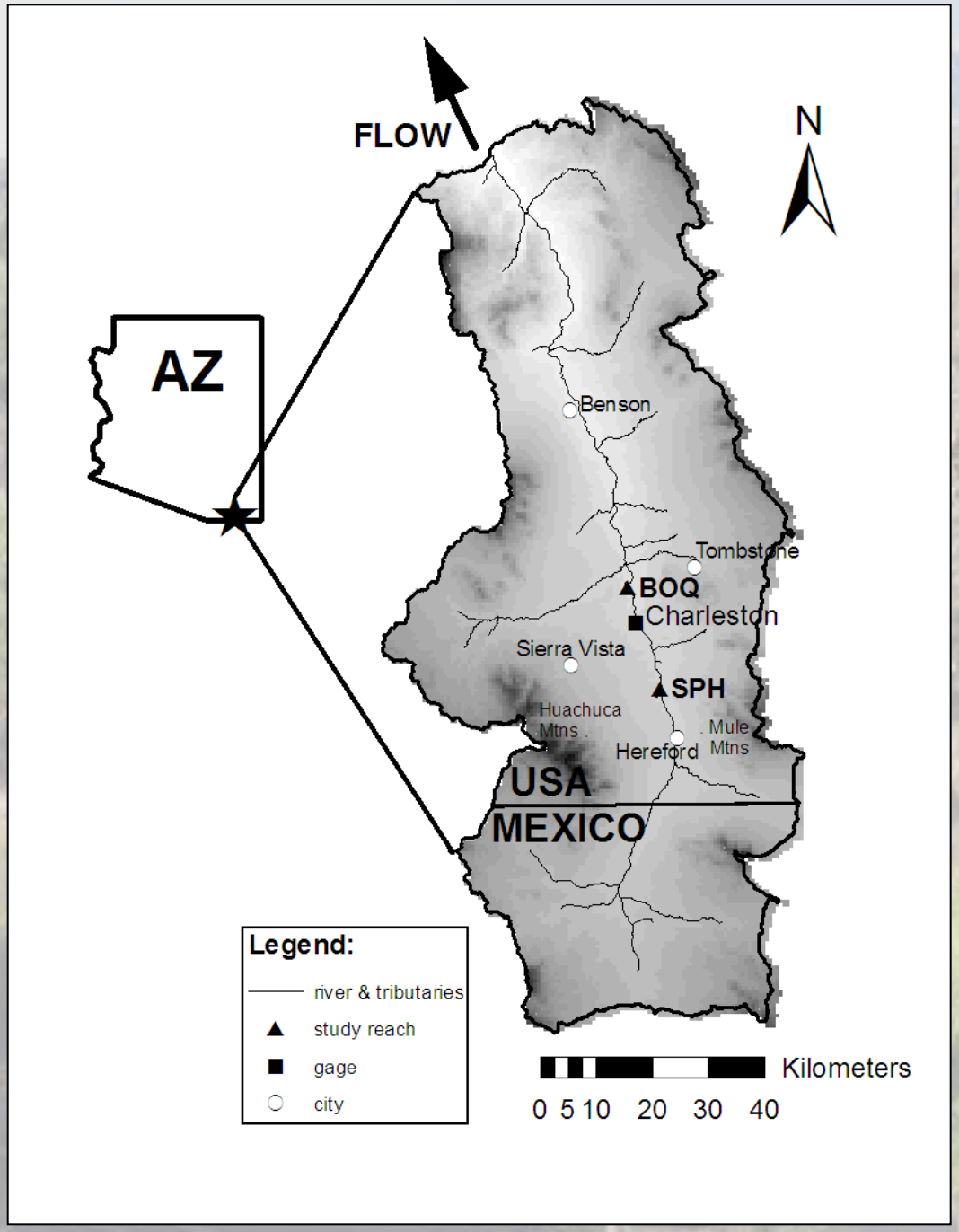
Ephemeral Streamflow



Water Balance of Uplands



Renard et al. 2008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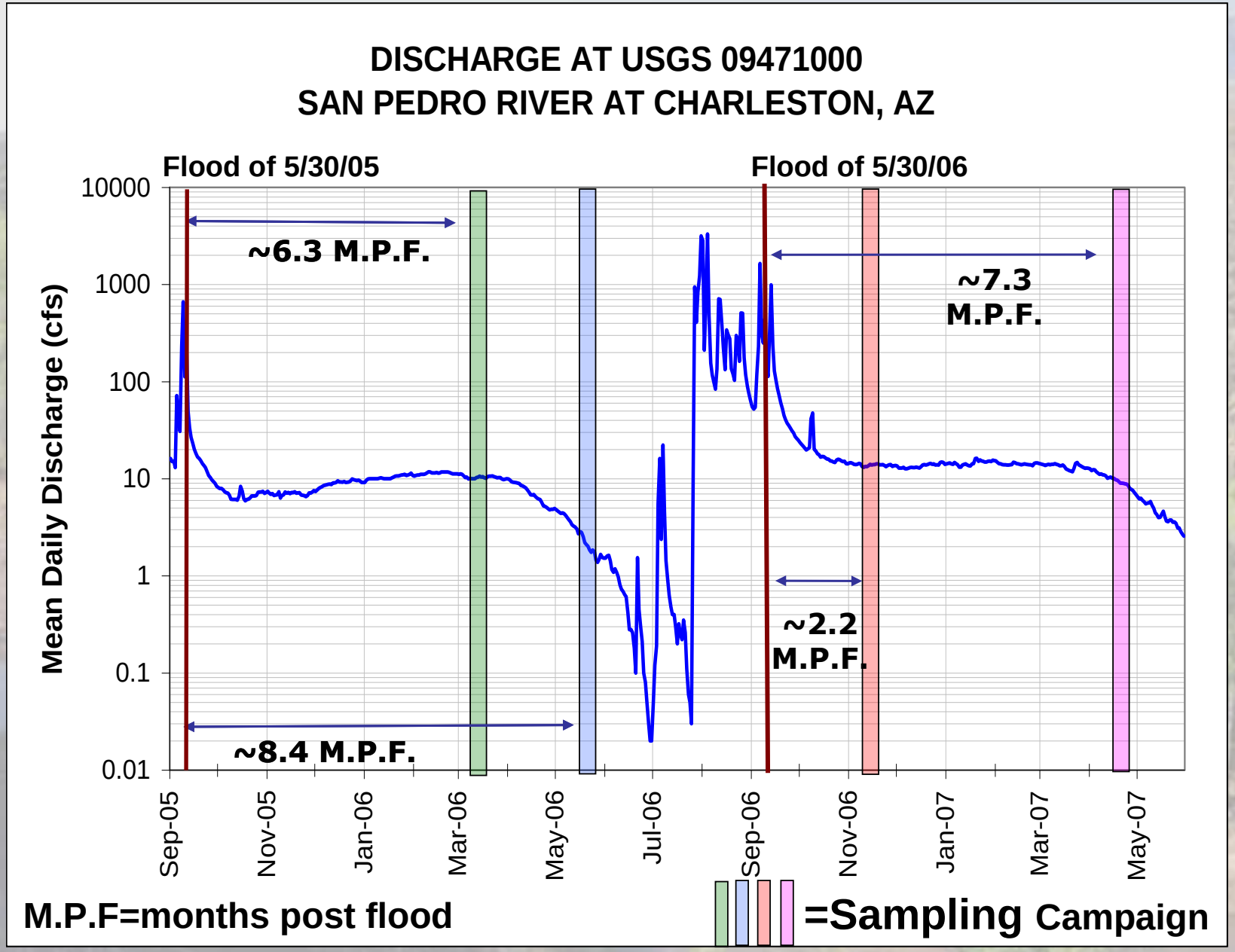
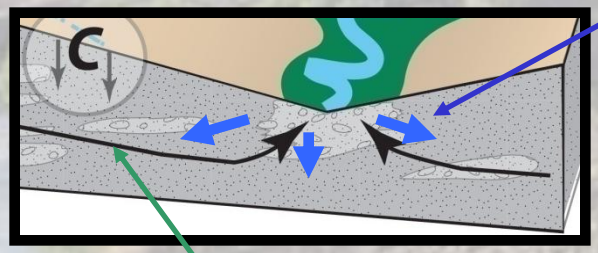


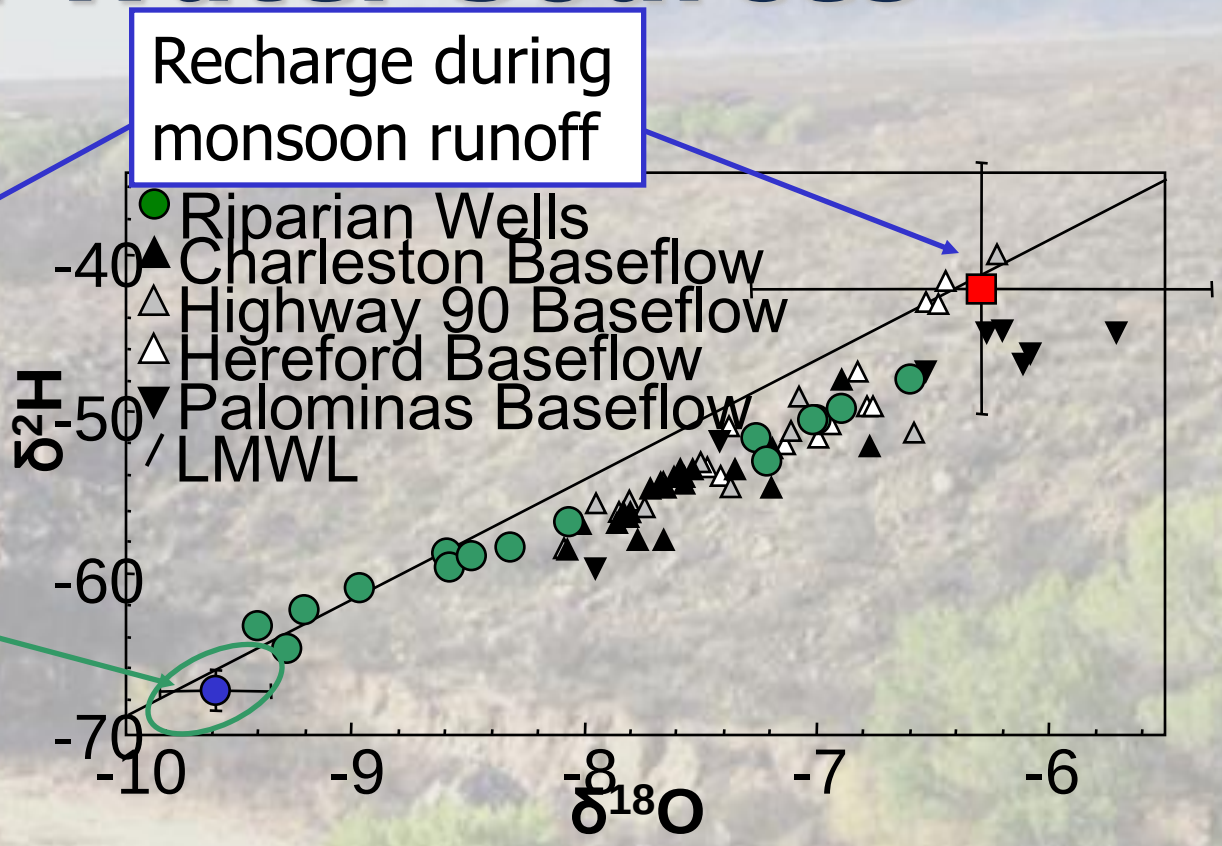
Personal Communication – Carlos Soto

Riparian Water Sources



Recharge during monsoon runoff

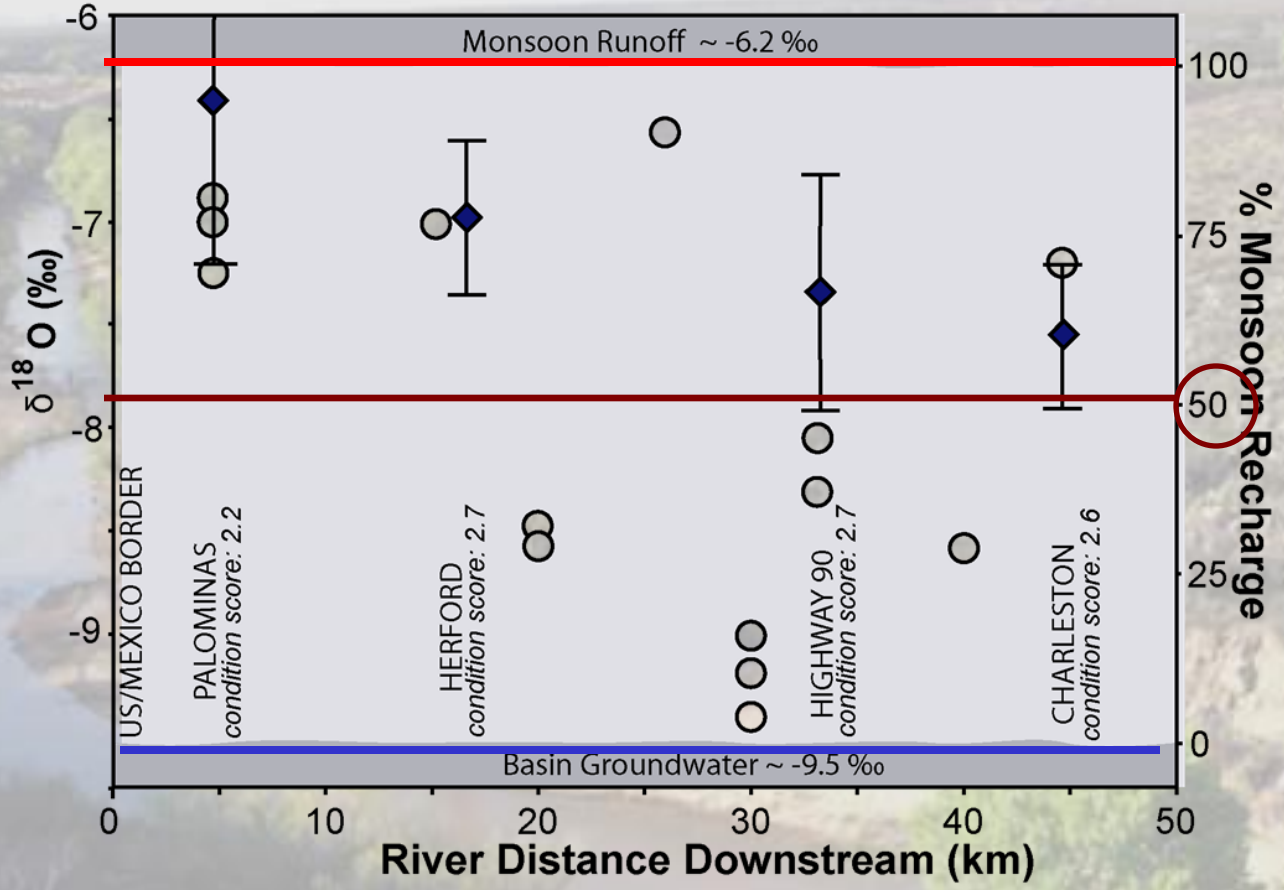
Basin Groundwater



- Isotopes of water – natural tracer of source
- Riparian wells span range between end members
- Baseflow skewed toward monsoon runoff
- Quantify % using simple mixing model
- Uncertainty associated with runoff end member

Baillie et al., 2007 JGR

Riparian Water Sources



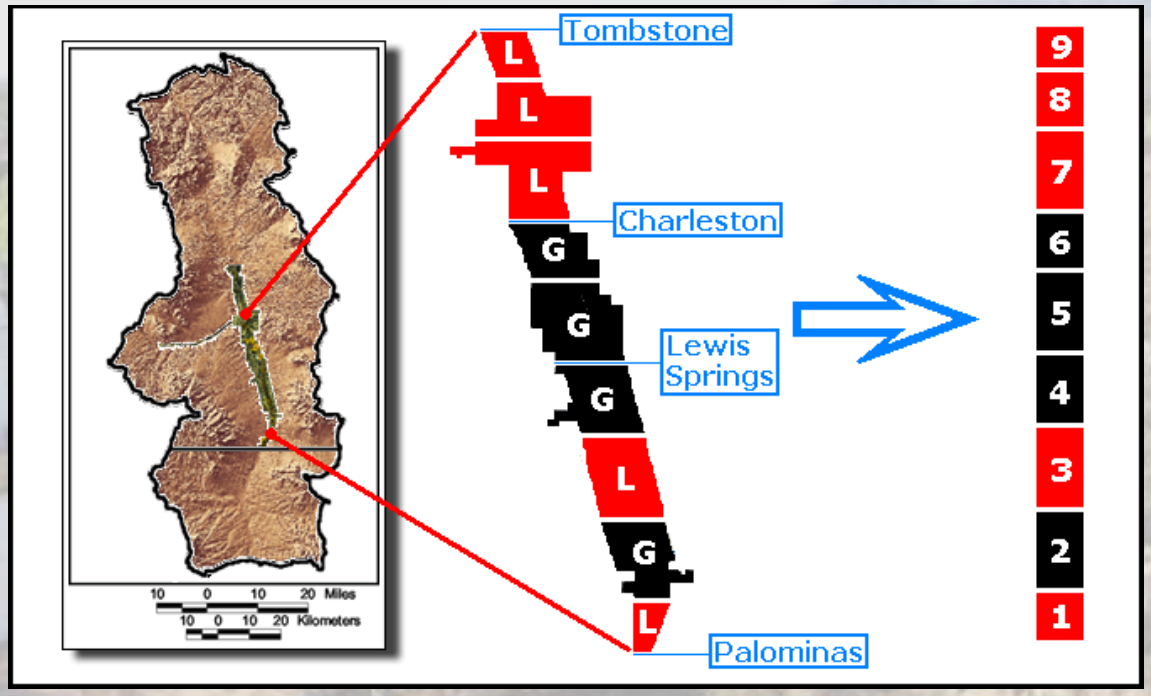
◆ Baseflow

○ Riparian Groundwater

- **Baseflow >50% monsoon runoff regardless of season**
- **Riparian groundwater variability related to gaining / losing status**

Baillie et al., 2007 JGR-B

Thursday talks by Soto and Simpson provide follow up research


Tombstone
Charleston
Lewis Springs
Palominas
L
L
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G
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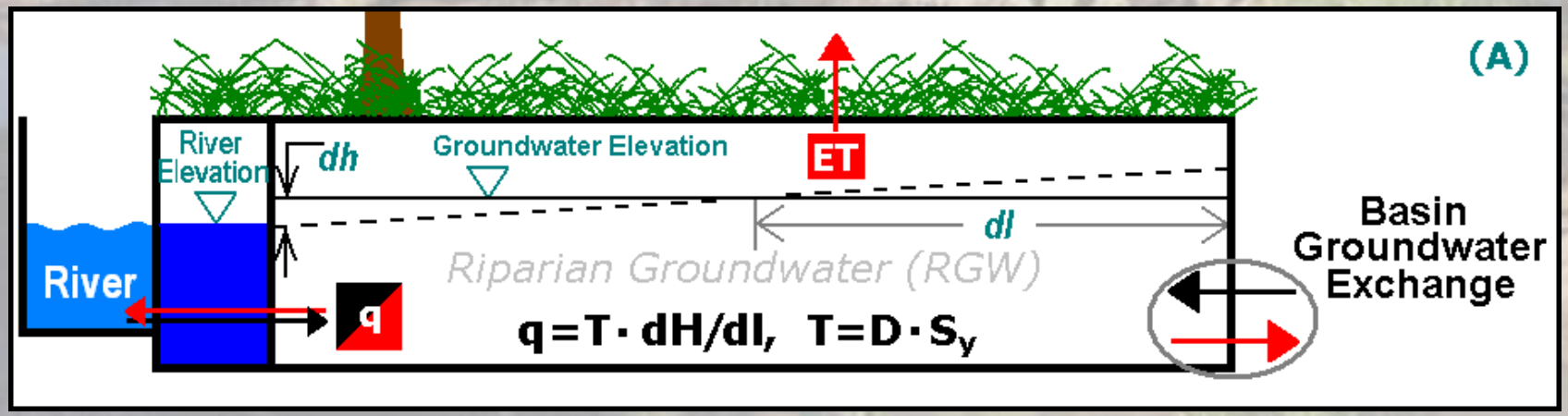
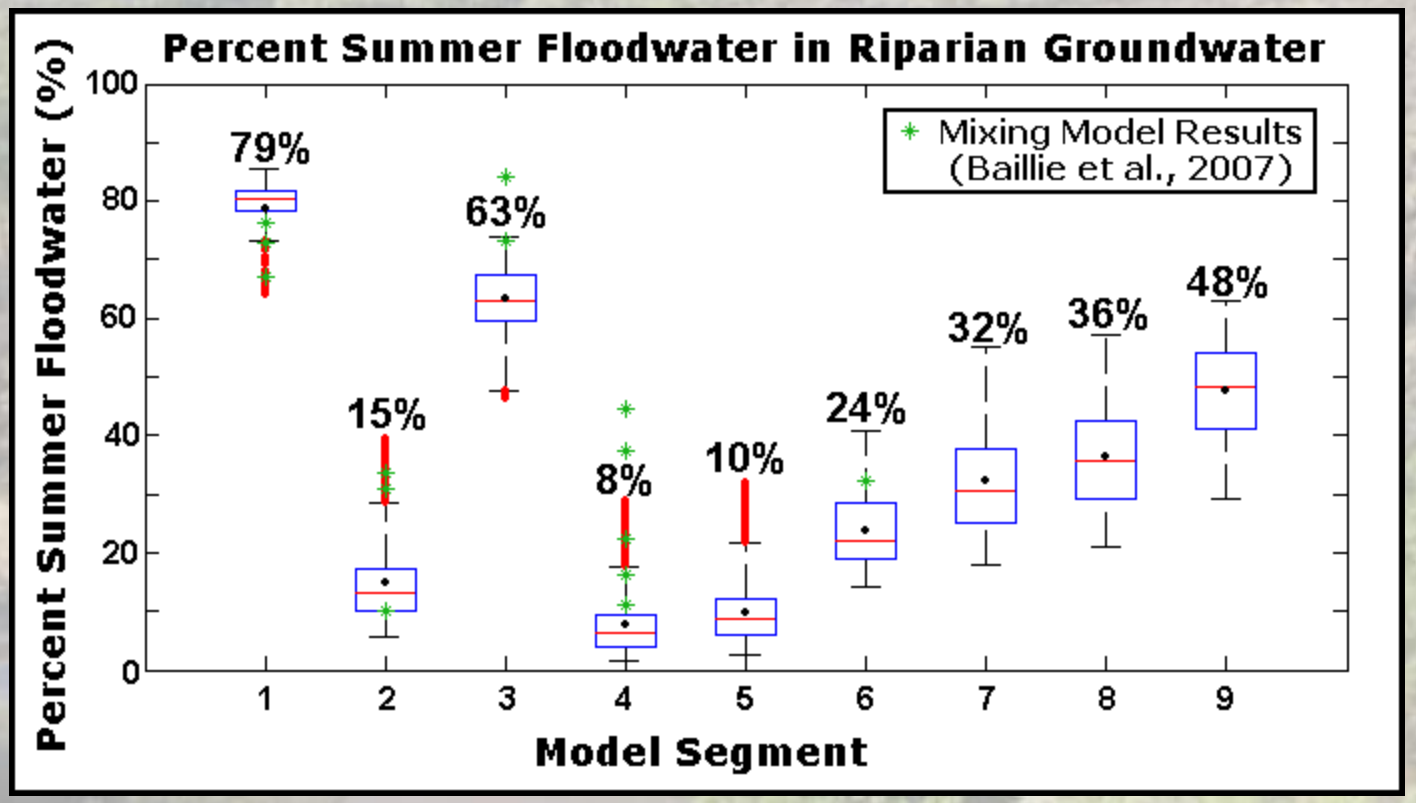
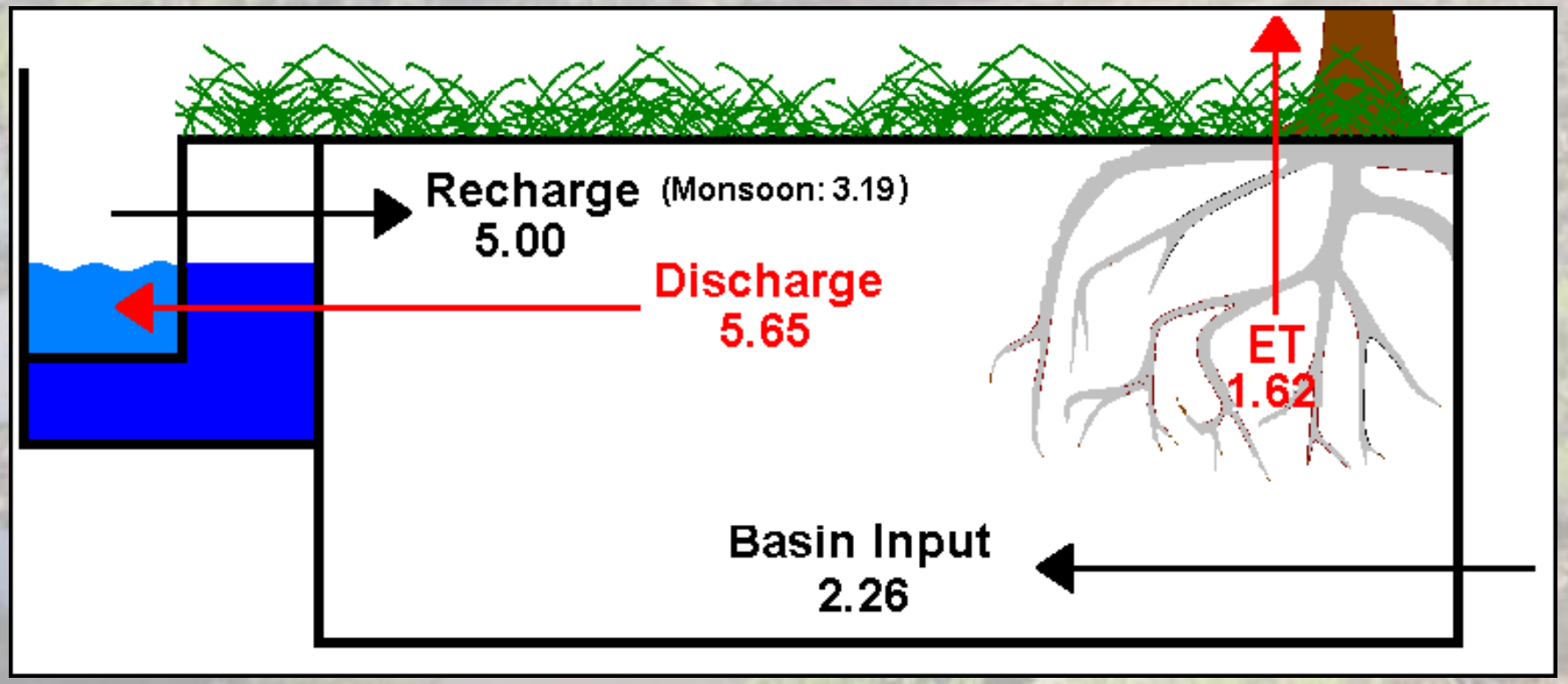
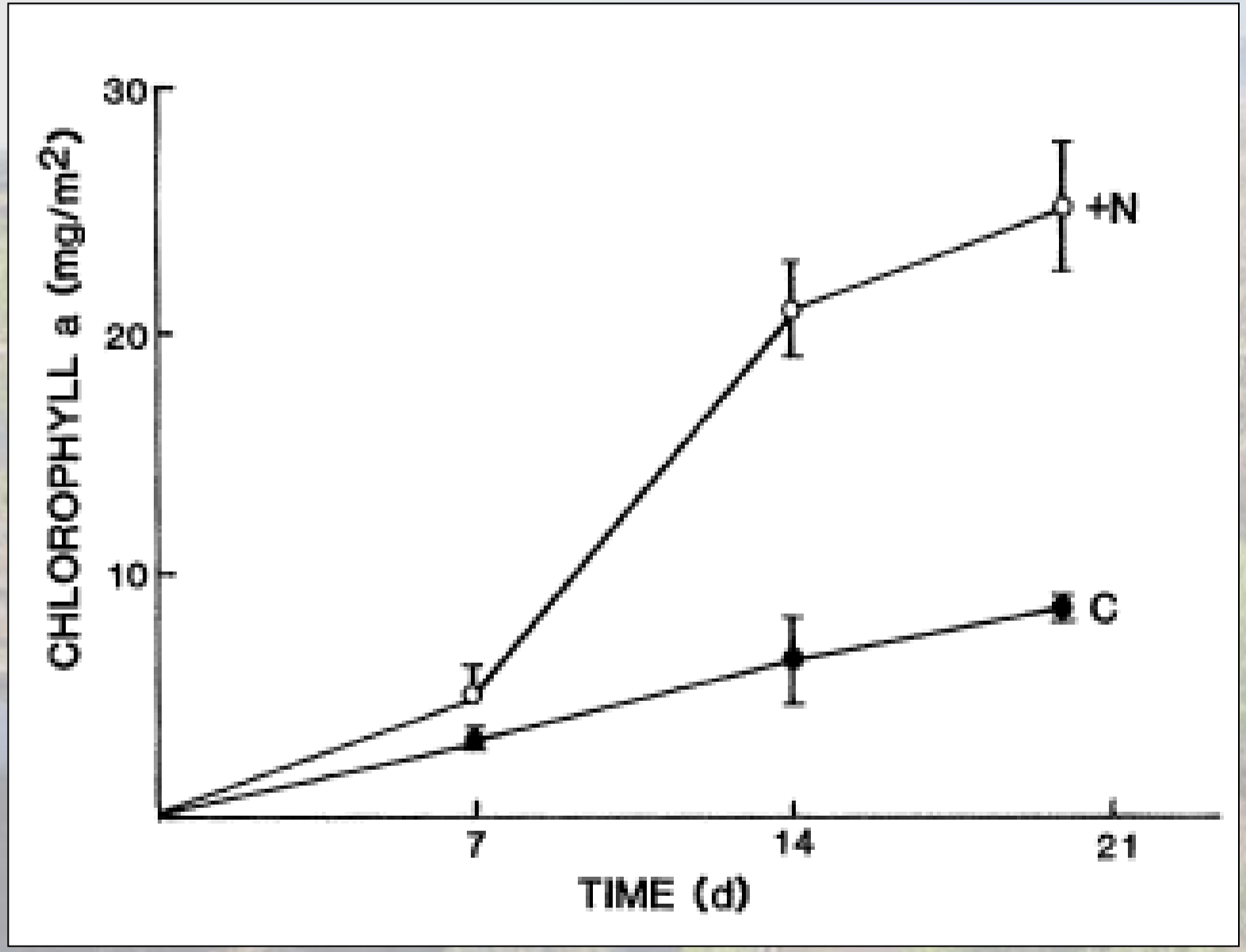
7
6
5
4
3
2
1
10 0 10 20 Miles
10 0 10 20 Kilometers


(A)
River Elevation
dh
Groundwater Elevation
ET
dl
Riparian Groundwater (RGW)
River
q
q=T·dH/dl, T=D·Sy
Basin Groundwater Exchange


Percent Summer Floodwater in Riparian Groundwater
Percent Summer Floodwater (%)
Model Segment
Mixing Model Results
(Baillie et al., 2007)
79%
15%
63%
8%
10%
24%
32%
36%
48%
0
20
40
60
80
100
1
2
3
4
5
6
7
8
9

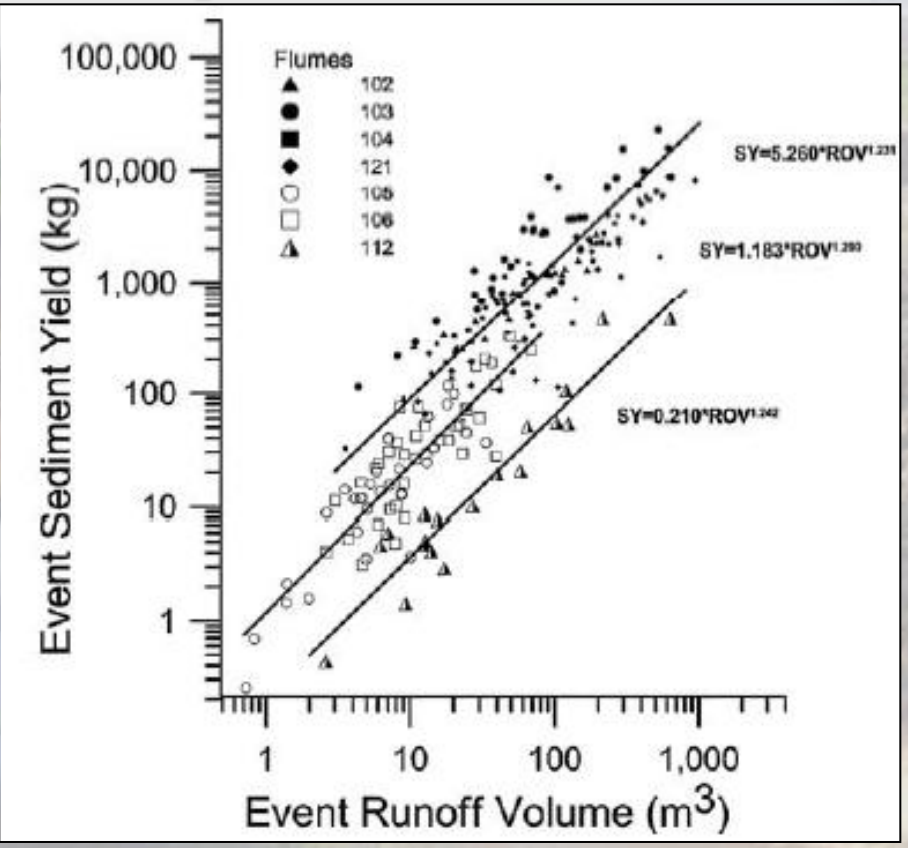
Can Flood Mechanism be Modeled Simply?

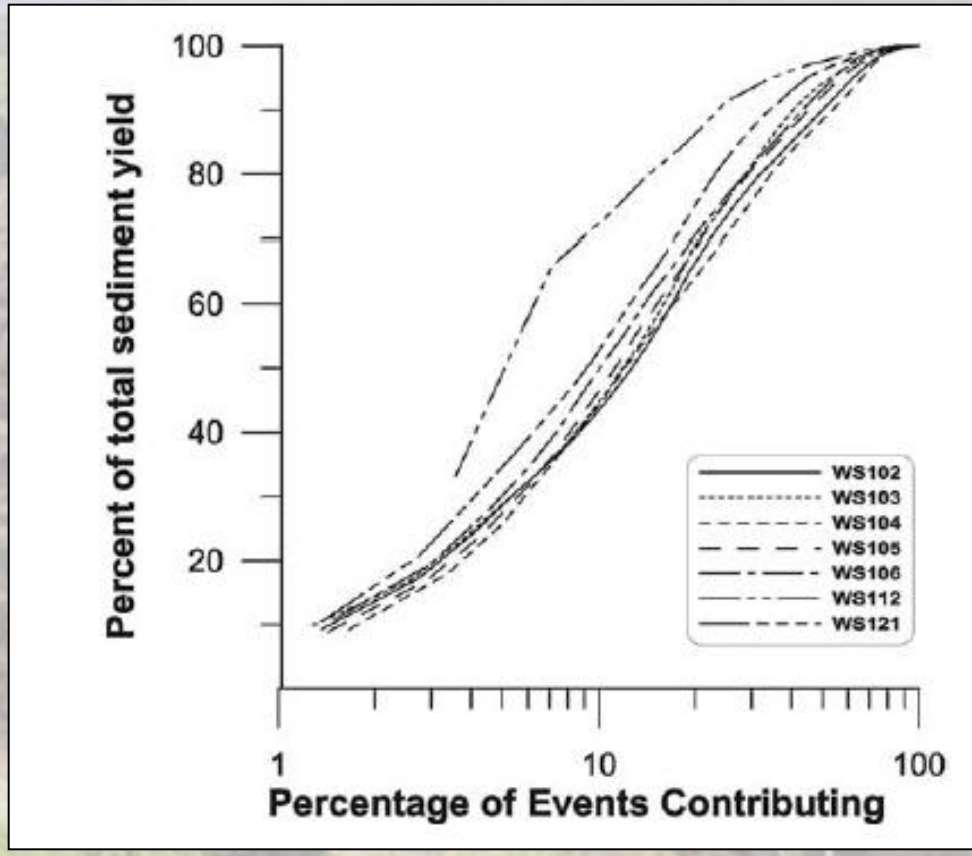




Grimm and Fisher 1986 JNABS **5,** 2-15

Uplands Erode – Biggest Events





Nearing et al WRR 2007

Sediment Yield Decreases with Scale

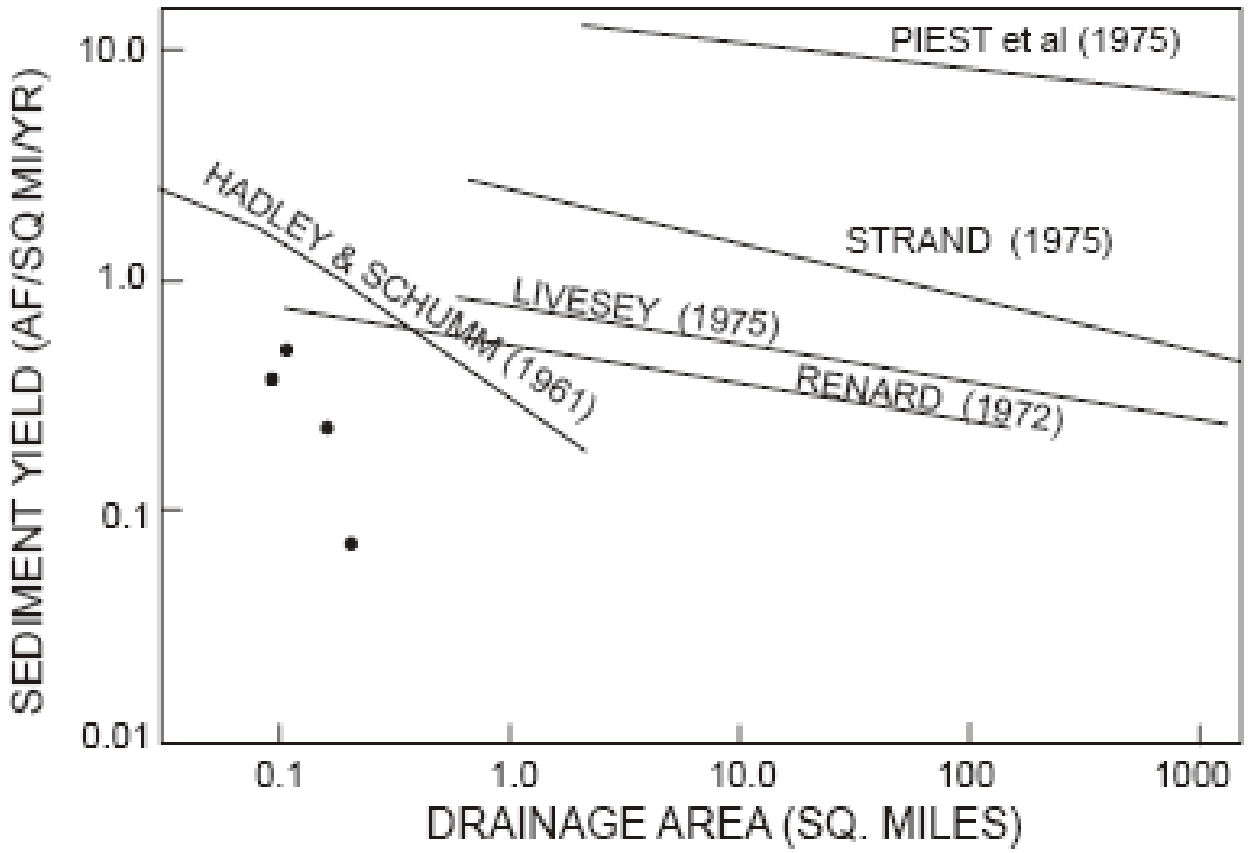
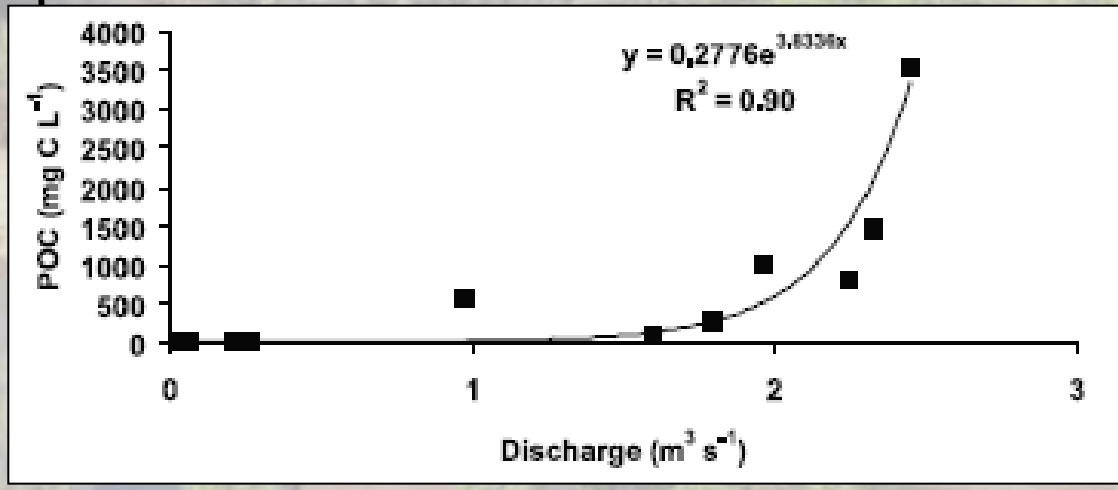


Figure 6. The relationship between sediment yield and watershed area including 4 WGEW stock tank watersheds (Branson et al. 1981. Figure 6-24).

Suspended Sediment Carries Organic Matter

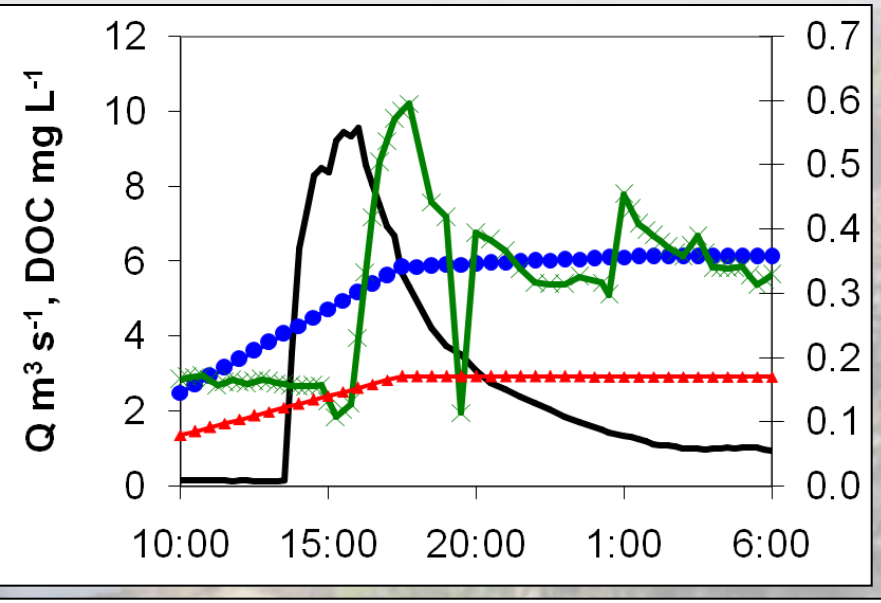
- According to Nichols et al 2006
  - Average Suspended Sediment yield from small catchments is 195 kg ha^{-1} $year^{-1}$
  - Calculated as spilled = suspended
- Using Data from Rhoton et al 2006
  - Carbon export from uplands is 4.7 kg-C ha^{-1} $year^{-1}$
  - With C/N ratio of 14.7 this means 0.318 kg-N ha^{-1} $year^{-1}$
- Observed Flux at Boquillas was
  - ~300,000 kg POC
  - ~ 20,000 kg PON
  - Both 500 times
  - smaller than scaled
  - upland flux

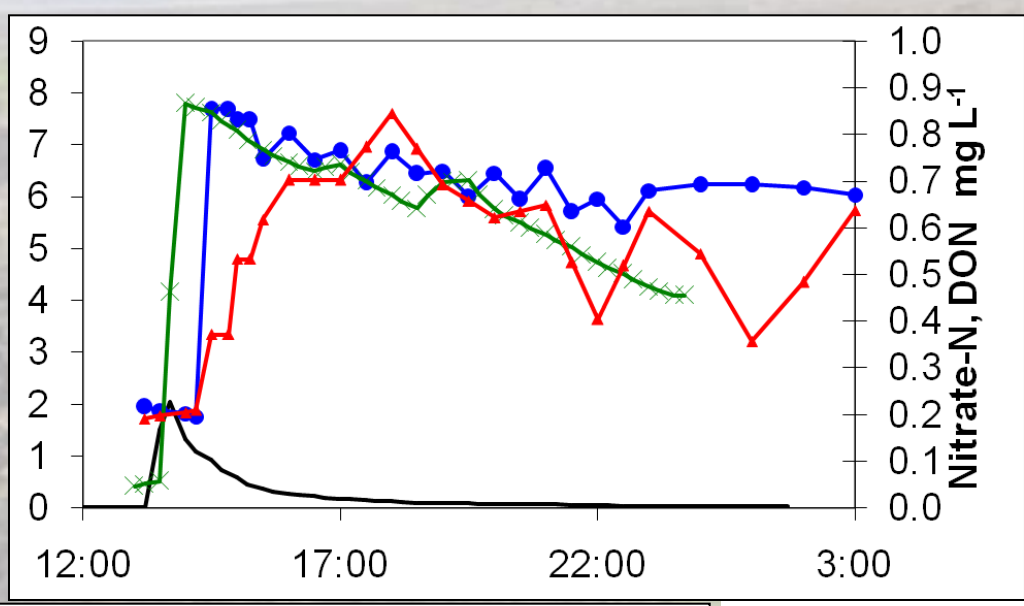


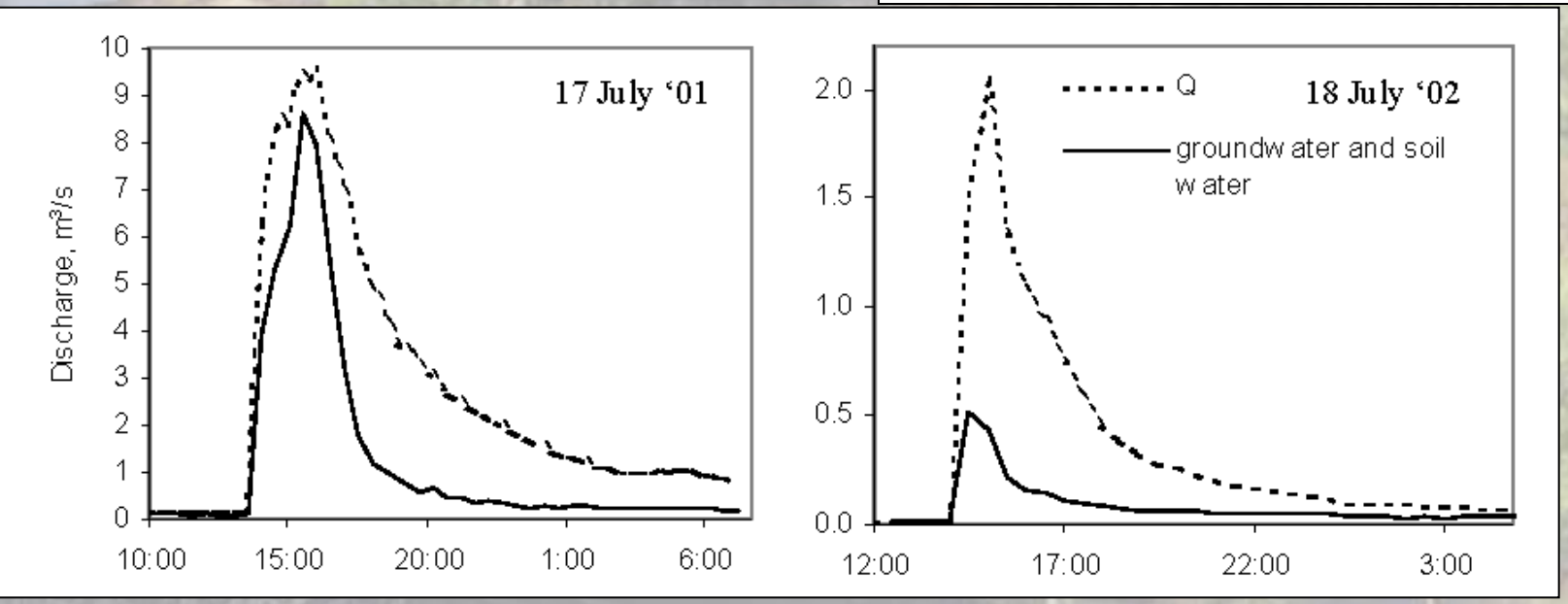
- Obvious sediment redistribution within system

Brooks, Haas and Huth 2007 - JGRB

Floods Remobilize Nutrients







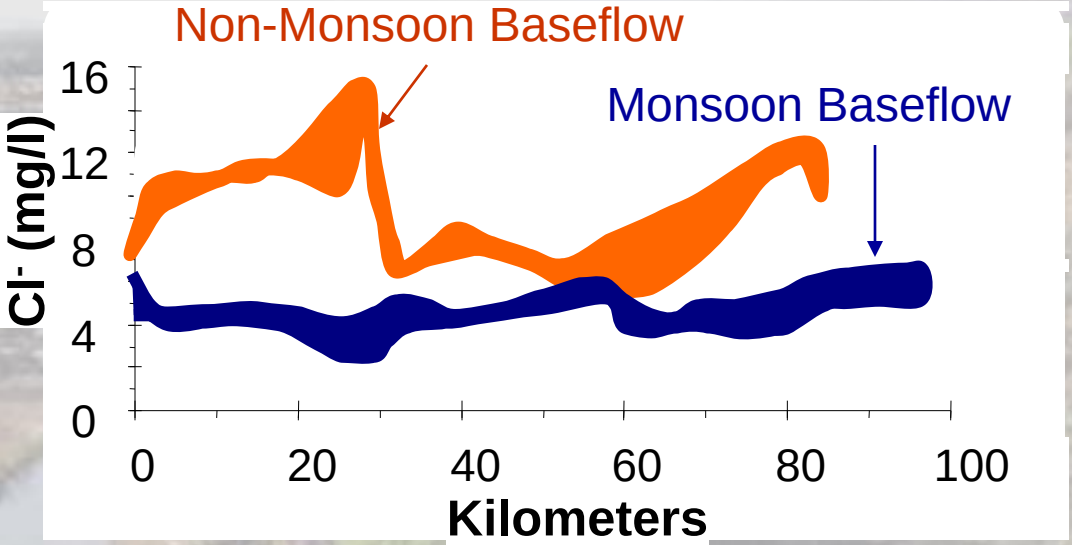
—Q

—●—DOC

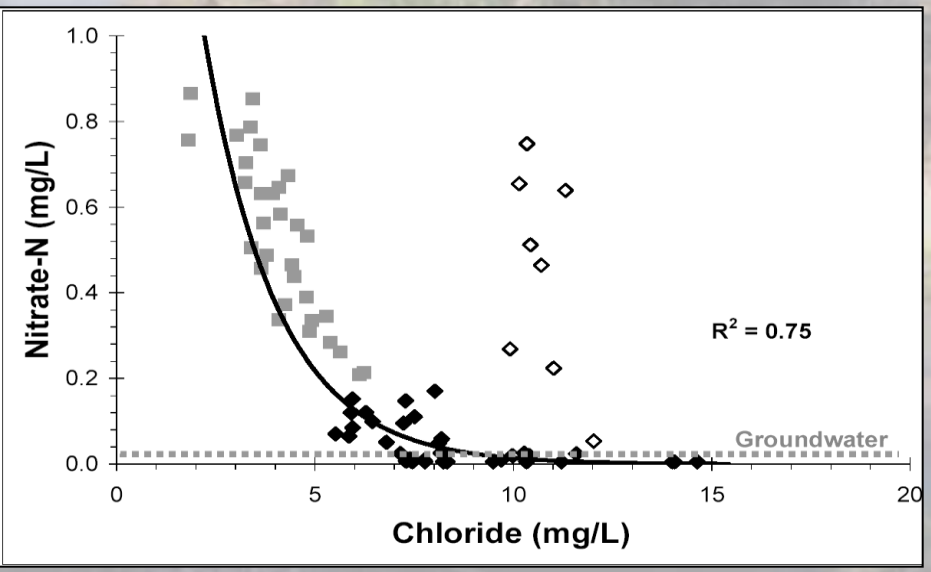
—✳—Nitrate-N

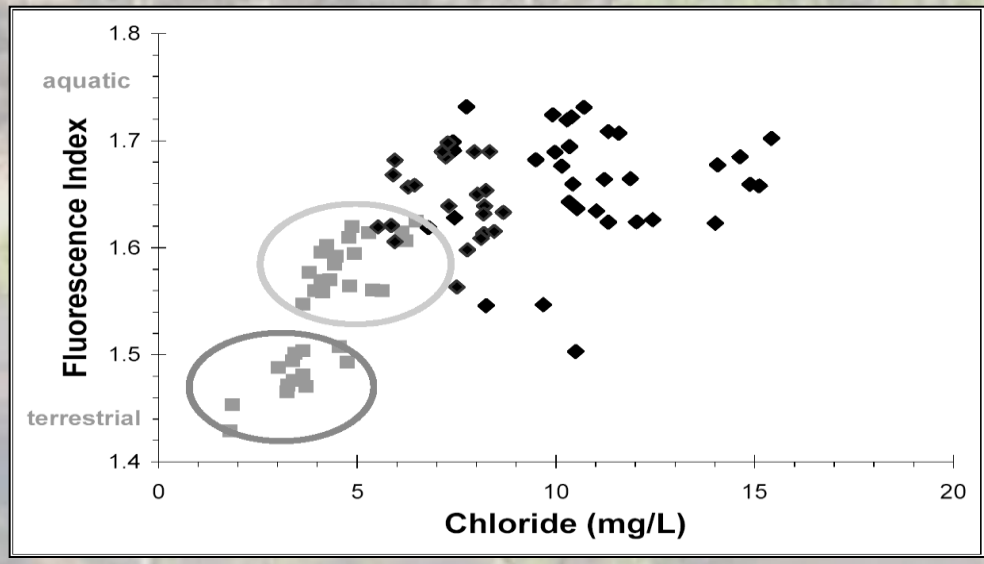
—▲—DON

Nutrients at All Scales From Terrestrial Source



- Pre-Monsoon River disconnected
- Change increases inorg. N
- Organic matter (FI) indicates change - influx of terrestrial organic matter





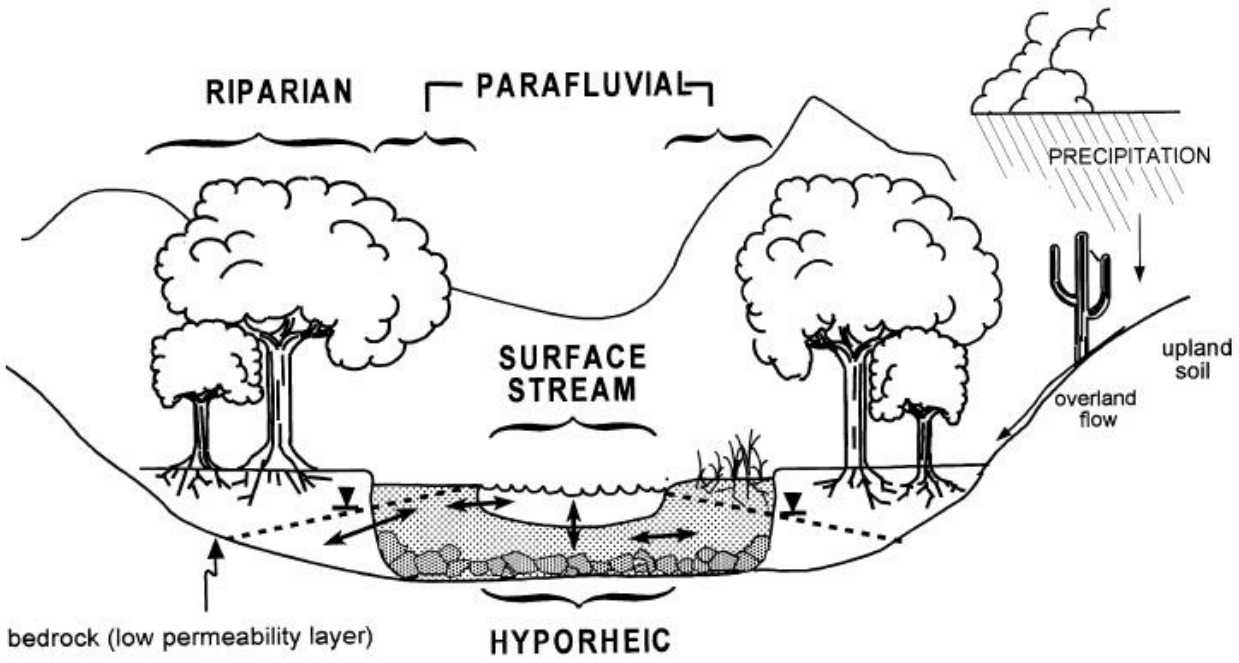
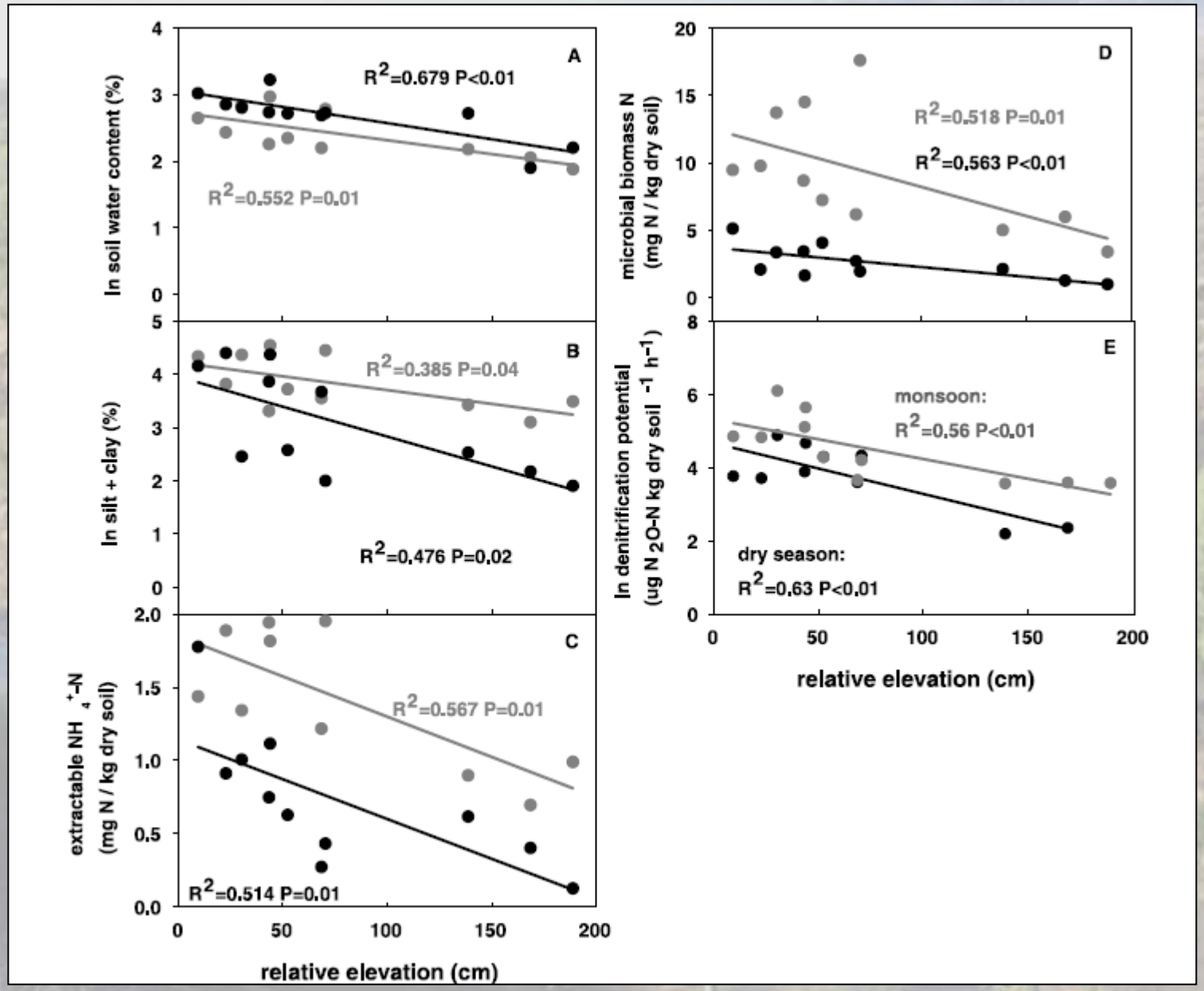


Figure 1. Diagram of the stream-corridor ecosystem in cross section, showing the surface stream, hyporheic zone, parafluvial zone, and riparian zone subsystems. The water table is shown by dashed line, and double-headed arrows denote hydrologic interactions among subsystems (cross-links).

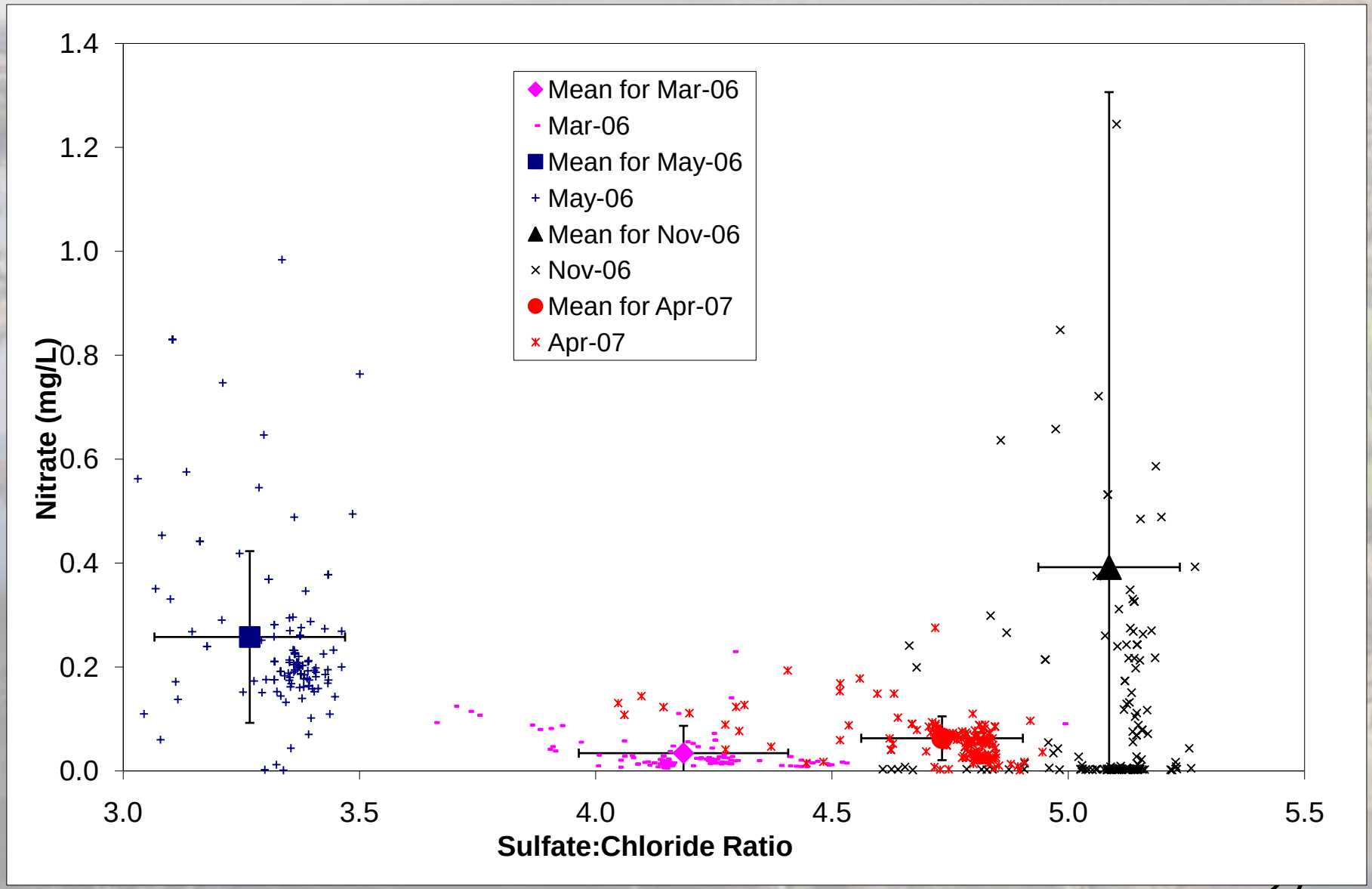
Fisher, S. G., N. B. Grimm, E. Marti, R. M. Holmes, and J. B. Jones Jr., Material spiraling in stream corridors: a telescoping ecosystem model, *Ecosystems, 1*:19-34, 1998.

Wetter Places Process More



Harms and Grimm 2008

Monsoon's Sustained Impact on Water Quality



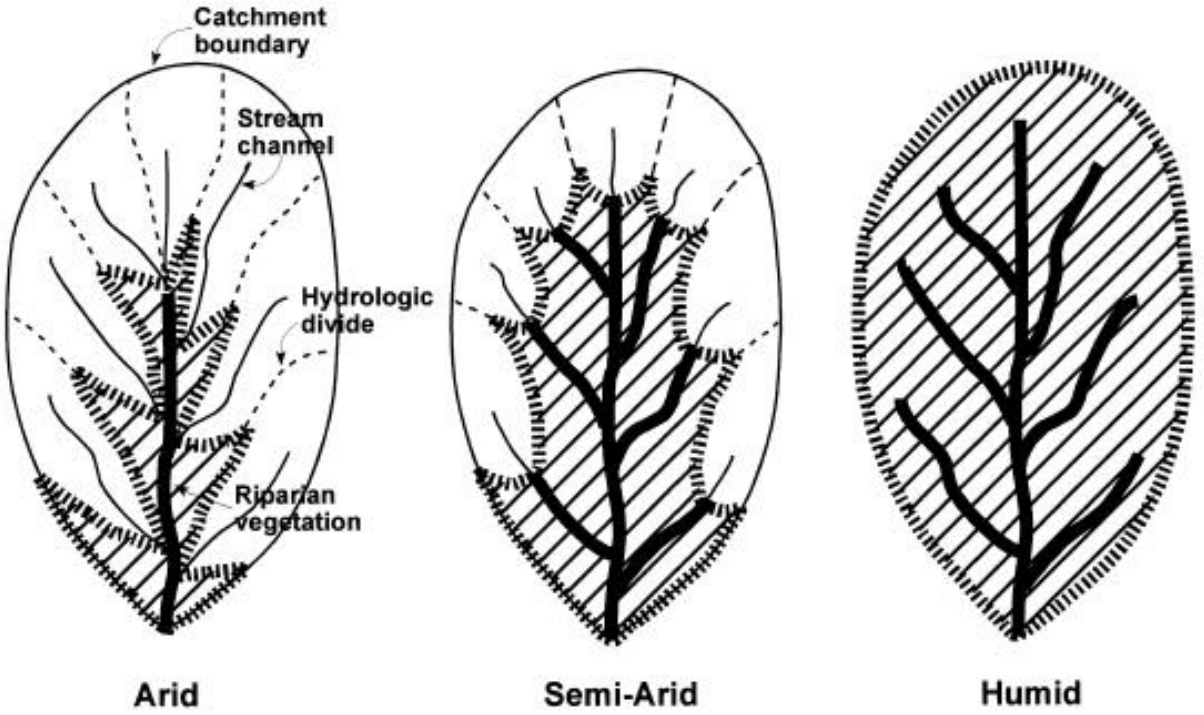


Figure 10. Extent of interception of laterally flowing runoff by riparian zones in arid, semiarid, and humid watersheds. In arid regions, riparian vegetation is restricted to larger channels whereas, in semiarid regions, gallery forest may occupy only the lower reaches of tributary streams. In humid areas, riparian vegetation is found along the lengths of all tributaries in a forested catchment. Runoff from the shaded area of catchments must move through the riparian zone before entering the stream channel. Runoff from the unshaded areas enters the stream channels directly.

Fisher et al. *Ecosystems*, ***1***:19-34, 1998.

Conceptual Model For Arid and Semi-arid Catchment Biogeochemistry

Nutrients Move React and Repeat

Arrive At riparian Area

Consistent Wet Conditions Allow for More reactions

Continuous pumping by stream and ET allow for continuous mixing

Dry conditions may allow disconnection within Riparian area

Future Research Directions

- How is suspended sediment redistributed within the system?
  - How is it reprocessed?
  - What effect does it have on hydraulic properties?
- How does flood magnitude influence annual scale groundwater fluctuations?
  - Impact on biogeochemical processing
  - Impact on nutrient conditions
  - Impact on Water Quantity
  - Mechanism of storage and release
- What is influence of sediment quality on water quality within system?

Acknowledgements

- Bureau of Land Management
- The Nature Conservancy – Holly Richter
- UA- Water Resources Research Center

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # R833025